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Evaluating the economics of biodiesel in Africa

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ABSTRACT

Road transport in Sub-Saharan Africa is expected to rise in the coming years. Paradoxically, this expansion is occurring at a time when oil prices have reached new heights. Unstable oil prices do indeed increase the vulnerability of importers. However, it also presents them with a unique opportunity to explore promising technical options to help reduce their over-reliance on imported petroleum fuels. This paper takes a closer look at the potential for biodiesel, with an emphasis on fuels produced from oil palm, castor oil and jatropha in Ghana, Kenya and Tanzania, respectively. The paper provides an economic appraisal of biodiesels from these feedstocks, and sets the context for further discussions on biofuels in Africa.

Contents

1. Introduction

The Report of the Commission for Africa [1] highlighted the significance of the transport sector as an important component of the economy. Efficient transport systems are often associated with the provision of social and economic opportunities. As such transport and gross domestic product (GDP) have grown in a parallel relationship in the past, and some decision makers even consider the supply of transport infrastructure as a precondition to foster productivity. Put simply, transportation is an economic factor of production of goods and services that facilitates market access by linking producers and consumers.

Road transport is the dominant means of moving goods and services in Africa. It accounts for about 85% of the total fossil fuel consumed in the transport sector. Of the total, diesel fuels amount to over 55% of the final fuel consumption in transport, highlighting the importance of this fuel to the economy as a whole. This raises alarm since most countries import their fuel, which amounts between 25 and 30% of hard currency earnings for most of Eastern and Southern Africa during a normal year and reaching 40% when oil prices go up (Karekezi [27]).

In recent years, there has been much discussion about substituting petroleum diesel with biodiesel. What started in small group of biodiesel aficionados some decades back, the possibility of using domestically produced biodiesel has now entered into the

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policy domains of countries and financial institutions as one way to minimize the impact of high price of oil. With large landmass for farming, Sub-Saharan Africa is increasingly being viewed as a region with a fairly high potential for biofuel production. With mainly energy security in mind, a number of countries have begun their own national biodiesel programmes.

This paper will explore the potential for biodiesel in Sub-Saharan Africa, using three cases: Ghana, Kenya and Tanzania. The analysis will look at country specific issues in relation to biodiesel production as well as carrying out a comparative economic analysis and greenhouse gas (GHG) emissions of blending 20% of the total consumption with biofuels. The paper will also provide a discussion on the implications a large-scale biodiesel programme will have on land use, food supplies and poverty reduction.

2. Transport fuels in the energy mix in Africa (and costs)

Over the past decade, consumption of transport fuels in Sub-Saharan Africa has increased at a rate of about 7% per year in line with increased economic activity (Fig. 1). Much of this fuel consumption growth is occurring in the road sector, which has registered an annual growth rate of about 8% since 1999, while fuel consumption in aviation and other sub-sectors has only seen a marginal increase. The importance of road transport in this growing trend can be observed in the growth of diesel fuel use, which has been rising at an average rate of about 13% per year since 1999. Fuel consumption will therefore continue to play an important role in transport policy in the light of these trends, particularly since most countries in Africa are fuel importing countries with inadequate foreign exchange reserves.

Some 39 countries in Africa are net oil importers. As the high price of oil persists into the future, these countries which are among some of the poorest countries in the world will be negatively affected. According to a recent report from the African Development Bank (2006) [16], about 39% of the total energy consumed in Sub-Saharan Africa is imported against a world average of 19%, confirming the heavy dependence of imported fuel. This situation exerts a heavy toll on the health of public finances, ultimately to the detriment of public services and profitability of oil-consuming businesses. Faced with balance of payments constraints, countries are likely to be forced to reduce both oil and non-oil imports, and in many cases external borrowing will need to be extended to finance budget shortfall brought about (or exacerbated) by high-oil-import bills.

Inevitably, this would lead to higher debt servicing and debt sustainability problems. Already, the average share of oil imports against total imports in Africa was running at about 12% in 2005, with figures as high as 25% observed for Kenya and Zimbabwe. This trend is expected to remain the same as the price for oil is likely to continue rising with increasing global demand for oil products. Since 1999, the average price of crude oil has increased from about US$28 to over US$70 per barrel in June 2007 [2,3], $97 in November 2007 [4] and $135 in May 2008 [5]. For a country such as Kenya, this represents an oil-import bill increase of more than 46% between 2003 and 2005, from US$880 million to US$1302 million [6]. Quite clearly, this illustrates the inextricable link between oil-import bills, economic performance, budget deficits and potential social unrest, all of which may exist in some combination already.

Against this backdrop of volatile fuel prices, many of the economies in Sub-Saharan Africa have shown remarkable resilience. According to the IMF's African Regional Economic Outlook [7], economic growth is projected at 5.3% in 2006, about the same rate as in 2005. Helped by windfalls from high-oil prices, oil-exporting African countries are expected to register a growth rate of about 8% this year, while oil importers will see their economy growing by about 4.5%, largely because of increased demand for other commodities such as copper, aluminium and coffee. This will have implications for the transport sector, which is expected to experience more activity in line with heightened economic demands across the continent.

Making the case for biofuels could not have come at an opportune time in view of both the economic and environmental urgency to follow a set of policies that simultaneously deliver on carbon reduction outcomes and address the vital issue of security of supply. Such engagements need to take place on all fronts and sectors in Africa as in elsewhere, and in this regard energy issues in transport can be pivotal in meeting these twin objectives. Recent progress in the Brazilian biofuels programme has highlighted the enormous opportunities that are open to African countries to reduce their dependency on imported oil and make meaningful contributions towards minimizing GHG emissions.

There are also potential dangers associated with the emergence of agriculture as a producer of transport fuels for which the market appears to be without limits. The temptation to increase the production of biofuels will inevitably increase the pressure to clear land for activities such as expanding sugarcane production (in the case of ethanol) and palm oil plantations posing new threats to animal and plant diversity. Furthermore, with the price of crude oil expected to continue rising, investments in fuel crop production and competition for land will create increasing pressure on traditionally farm-based economies. This soaring demand for agri-based fuel is coming at a time when world food stocks are at their lowest level in almost 40 years and when there are 76 million more people to feed each year [8]. Indeed, there are other cases where a major switch occurred in response to the volatility of certain commodities. For example, a major switch did occur in Latin America and the Horn of Africa from traditional food crops and coffee to coca and quat production as a response to diminishing returns in the commodities sector. This concern over food security is one which is very sensitive in Sub-Saharan Africa given the large number of 'food deficit' regions, and therefore assigning land for fuel will consist of significant policy challenges.

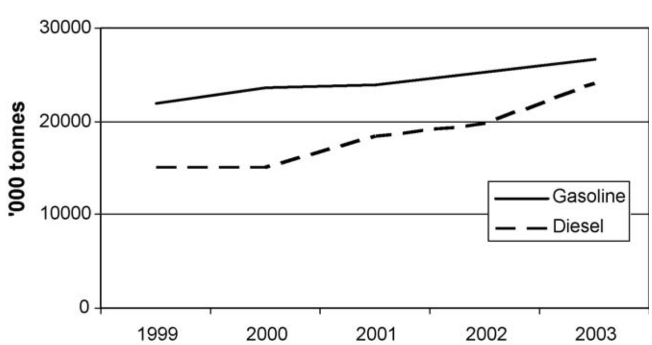

Fig. 1. Transport fuel in Africa (1999–2003). *Source*: IEA Energy Statistics (http://www.iea.org/Textbase/stats/index.asp).

3. The economic case for biodiesel in Africa: analysis from three countries

The three countries chosen for this study, Ghana, Kenya and Tanzania have similar diesel consumption characteristics (see Table 1). Moreover, there is a growing trend in diesel consumption in all three countries despite all three being oil-importing countries with potentially crippling debt problems (IEA Energy Statistics). Government response to the increasing world oil prices in all three countries has been to raise the price of oil products domestically, hence transferring some of the burden on their

Table 1
General data and assumptions.

	Ghana	Kenya	Tanzania
Diesel consumption in 2004 (l)(1)	524,000,000	574,938,000	599,781,000
10% biodiesel blend (l)	57,000,000	62,500,000	65,000,000
20% biodiesel blend (l) (incl. thermal conversion)	114,000,000	125,000,000	130,000,000
Feedstock(2)	Palm oil	Castor oil	Jatropha
Yield (in kg/ha)	23,700	4700	7000
Yield (in litres oil/ha)	5000	1700	2100
Energetic equiv. (kWh/ha)	178,000	60,520	74,760
Oil seed price ($/1000 kg)	120–210(3),(5)	300–500(4)	180–400(6)
Oil price ($/1000 l)	25–44	108–180	54–120
Price ($/ha)	2840–5000	1400–2350	1260–2800
Oil seed amount (t) 20% blend	540,390	345,213	434,310
Meal amount (t) 20% blend(7)	443,121	286,075	356,135
Land area required			
At 10% blend (in ha)	11,400	36,765	30,950
At 20% blend (in ha)	22,800	73,530	61,900
Capital cost ($) (excl. crushing plant)(8)	18,150,000	19,510,000	19,544,000
Pre-design ($)	405,000	417,000	425,000
Buildings ($)	2,000,000	2,000,000	2,000,000
Equipment ($)	8,950,000	9,740,000	10,165,000
Contingency (10%) ($)	1,650,000	1,773,000	1,840,000
Construction management ($)	855,000	930,000	970,000
Engineering and design ($)	2,855,000	3,100,000	3,230,000
Operation and start-up ($)	1,425,000	1,615,000	1,615,000
Crushing plant(9) ($)	14,575,000	15,990,000	15,990,000
Operating cost(10) ($)	112,620,712	124,914,400	111,280,400
Raw materials			
Oil ($)	86,463,000	103,564,000	86,862,000
Methanol ($)	4,180,000	4,668,800	4,810,000
Catalyst ($)	2,171,500	2,388,700	2,497,000
Crushing charge ($) ($30/t)(11)	16,212,000	10,357,000	13,029,000
Transport ($) ($0.013/l oil)(11)	1,710,100	1,873,000	1,954,300
Energy ($) ($0.014/l oil)(11)	1,596,100	1,748,000	1,824,100
Management/maintenance ($)	287,700	314,900	304,000
Income ($)	125,671,000	135,096,000	132,353,000
Sale of biodiesel ($)[a]	92,300,000	113,725,000	105,485,000
Sale of glycerin ($) ($200/t)(9)	137,000	150,000	158,000
Sale of meal ($) @ $75/t	33,234,000	21,231,000	26,710,000
Discount rates	5%, 9% and 12%	5%, 9% and 12%	5%, 9% and 12%
Current cost of diesel in domestic market[b] (US $)	0.88	0.99	0.88

Sources: (1) International Energy Agency Energy Statistics [9]; (2) Pelly [21]; (3) Asia Pulse News [22]; (4) Castorworld Market Intelligence www.casortworld.com [18]; (5) Barlow et al. (2003) [28]; (6) GTZ [15]; (7) Portnoff (2006) [29]; (8) (S&T)^2 Consultants and Meyers Norris Penny LLP [23]; (9) Booth et al. [24]; (10) [25]; (11) Pathak [13] and Reaney et al. [26].

[a] Sale of biodiesel = biodiesel blend (l) × local price of diesel × heating value ration (biodiesel/diesel).

[b] All Africa Global Media http://allafrica.com/ [17].

already economically beleaguered citizens. Between 2003 and 2006 alone, the price of diesel in the domestic market in Ghana, Kenya and Tanzania has risen by 160%, 32% and 21%, respectively [9]. The effects of such policies bring a particularly heavy burden on low-income households who already allocate a high proportion of their income for household fuel expenditures.

A study by Meikel and Bannister [10], undertaken at the start of a major oil price increase in Ghana has illustrated just how central energy is to livelihoods and how small increases in the price of oil often have profound social and financial implications that require major livelihoods 'adjustments'. Sometimes these forced 'adjustments' can reach breaking point, which are expressed in active social unrest that contribute to broader political and economic instability. There are several examples of these across Africa; some serious as in the case of Zimbabwe and many minor ones as in the three countries being investigated in this paper. Of course, No one can make the claim with certainty that high-fuel prices alone ultimately lead to some form of social unrest. The conditions for such an eventuality are often complex and have their root in social relations and governance, but adding financial pressure on already economically stressed households is likely to increase the possibility for social disquiet.

Against this background, it may possible to argue that producing indigenous energy resources relieves the pressure on governments to resist the temptation of knee-jerk fuel price increases that have adverse impact on the poorest sections of their population. The recent discussion surrounding biofuels in Africa is partly an attempt to take more control and sovereignty over energy supplies by exploring how much of it can be obtained from domestic sources. The discourse has nuances of energy security, poverty reduction and fiscal stability, and biofuels are increasingly seen as one of the various energy resources that almost any country with 'surplus' land and labour resources can exploit through relatively low-capital inputs and medium levels of management.

In view of the numerous oil crops that can be grown to produce biodiesel, this paper will explore three different types (feedstock) assigned to each country based on the appropriateness of the crops to specific climatic conditions. The paper will evaluate palm oil in Ghana, jatropha in Tanzania and castor oil in Kenya as the

feedstock for producing biodiesel. The cases will be considered together in order to provide both a comparative analysis and a case-specific appraisal about the economics and environmental impact and benefits associated with each feedstock.

4. Methods

The assumptions used for the financial analysis are intended to account for all major changes. Key inputs to the financial analysis include capital cost of crushing and bio-refinery technology (including energy input and personnel costs), cost of feedstock, economic life (15 years) under three different discount rates. These are given in Table 1.

The costs associated with the biodiesel system consist of three categories: investment, fuel costs and operation and maintenance (O&M) costs. While capital and O&M costs are independent of the production quantity, the fuel cost is variable and depends on changes in conversion technology as well as fluctuating fuel prices over time. Hence, it is imperative to employ an economic analysis that takes into consideration the varying value of money with time. One such method is life-cycle cost (LCC), which quantifies the cost, starting from the construction phase to the end of its economic life. LCC includes the cost of initial investment costs (C_i), the sum of recurring annual payments (fuel, O&M) discounted to their present value (Pv_r), and the sum of all replacement costs minus decommissioning costs (discounted to their present value)—also known as single future payment (Pv_s).

The recurring annual payment (Pv_r) and single future payment (Pv_s) are obtained from the following two equations:

$$Pv_r = \sum_{1}^{n} C_{ap} \cdot \left[\frac{x(1-x)}{1-x}\right] \tag{1}$$

where $x = (1 + i)/(1 + d)$, C_{ap} = annual payment, i = interest rate, d = discount rate, n = number of years for which payment is made.

$$Pv_s = C_s \cdot \left[\frac{1+i}{1+d}\right]^n \tag{2}$$

where C_s is the single future cost

Hence, based on the simple relations in Eqs. (1) and (2), the life-cycle cost (LCC) of a project (or programme) may be derived in the following way:

$$\mathrm{LCC} = C_i + Pv_r + Pv_s \tag{3}$$

The final results of the LCC exercise can be presented in a number of ways. These include *annualized life-cycle cost* (ALCC) which ascribes to the total of LCC expressed in terms of a cost per annum which is done by the reverse of discounting. Another approach is to employ what is known as *levelized cost* which refers to unit energy cost, which refers to LCC per total production (or demand) over the study period. The levelized cost is used in this study, and is obtained from the following equation:

$$\text{Levelized cost} = \frac{\mathrm{LCC}}{\text{total biodiesel production}} \tag{4}$$

One of the most important aspects of biodiesel (crushing + bio-refinery) economic analysis is deciding what future energy prices to use in the calculation. While energy forecasting is difficult under any circumstances, the recent historically high prices have compounded the degree of uncertainty regarding the future. For this reason, it is deemed important to undertake sensitivity analysis.

The objective of a sensitivity analysis is to identify critical inputs of the financial model and how their variability impacts on the result. In other words, by varying the inputs over a reasonable range of uncertainty and observing the relative change in model response, it is possible to acquire an understanding about the parameters that influence process dynamics [11]. For the case of this paper, sensitivity uncertainty in the price of diesel as well as feedstock and meal prices is carried out to have a robust understanding of the level of risk associated with biodiesel investment in the three countries considered. It also helps to clarify how sensitive the output is to the specific inputs and therefore identify the key variables. This involves changing the value of these variables at a time and calculating the resulting change in the life-cycle cost of the biodiesel programme.

5. Economic analysis of biodiesel (B20)

As discussed earlier, no modification of diesel engines is required for biodiesel blends of up to 20%. The analysis herein will explore the substitution of 20% (also known as B20) of petroleum diesel with biodiesel using a different feedstock in each of the three countries. The baseline data for diesel consumption will be 2004 (see Table 1). Also shown in Table 1 are the other assumptions including capital cost for various plant sizes, capital cost for the crushing plant, and O&M for the different plants as well as income the sale of biodiesel and its various co-products. It is estimated that diesel consumption will increase at an annual rate of 5% into the foreseeable future, indicating that in order to maintain a 20% biodiesel blend the amount produced and sold would need to increase every year. However, the analysis in this paper will be restricted to capture the substitution of biodiesel for the baseline year of 2004 in order to have an appreciation of the long-term economics of meeting today's 20% share of diesel consumption.

The financial analysis for each country was carried out using 5%, 9% and 12% discount rates over 15 years of the biodiesel plant life. Fig. 2 shows that the levelized cost of biodiesel production falls in the range of $0.40 and $0.70 per litre. The calculation shows that jatropha in Tanzania performs better compared biodiesel from palm oil and castor in terms of production cost. Part of the reason for this is that the production cost of biodiesel from jatropha (as indicated in Table 1) per hectare appears lower than that of castor and palm oil, mainly because of the typically lower price for jatropha oil seed. Overall, as long as the price of diesel remains under $0.70 per litre, biodiesel can be regarded as an acceptable investment, particularly for oil-importing countries that face foreign currency shortages.

When the biodiesel production costs are offset by the income from biodiesel sales in the market, potentially substantial revenue can be generated in all three countries (Fig. 3). The revenue from using jatropha feedstock in Tanzania shows profits between US$0.06 and US$0.10 per litre of biodiesel. For investors willing to take risks in this type of venture are likely to do well in both

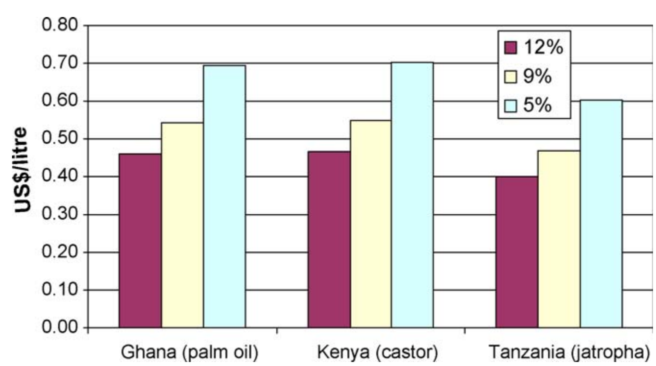

Fig. 2. Levelized costs of biodiesel production at a range of discount rates.

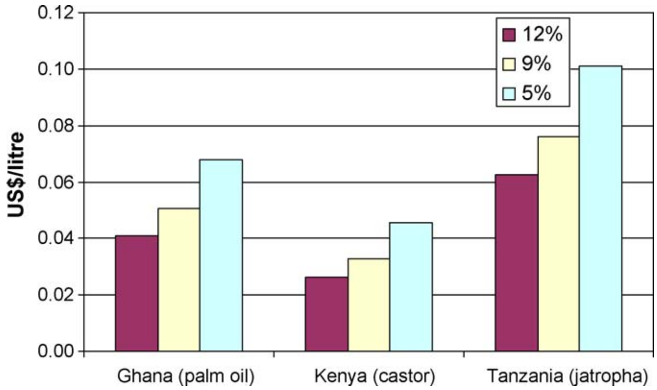

Fig. 3. Levelized income from sales—biodiesel production (revenue).

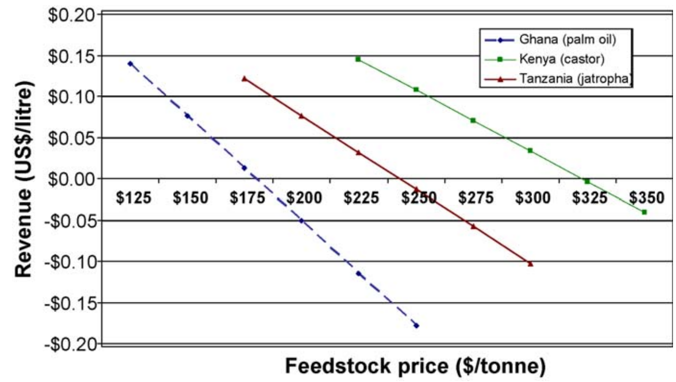

Fig. 4. Feedstock sensitivity at 9% discount rate.

Tanzania and Ghana. Revenue for biodiesel obtained from castor oil in Kenya shows positive results, although not quite as attractive as in the other two cases. A combination of three factors can explain this discrepancy. First, the yield per hectare from castor oil is about 194% lower than palm and a modest 25% lower than jatropha, and if the value of land is incorporated into the calculation, the figure could even be less favourable to castor. Secondly, the price of castor seed in the market place of $108–180/1000 l is significantly higher than that of the other two feedstock, largely because castor is a highly sought after commodity for a range of industrial purposes and productivity of castor seed per hectare is relatively low. Thirdly, the price for the meal co-product is an important in determining the economics of a biodiesel programme. In this case, the amount of meal obtained from castor is considerably lower than the yields from palm and jatropha, which can influence the overall level of income from biodiesel. Every year, there would be a difference of between $5 and $10 million provided the price of meal from the different feedstock in different countries remains the same. Of course, this may represent a big assumption but it indicates just how crucial meal prices are to overall costs.

Overall, given stable macro-economic conditions, biodiesel can become a competitive source of fuel. It could also offer lucrative business opportunity for those willing to invest and absorb the relatively high risks involved in the business of cash crops. For the three countries presented in this paper, which are net importers of petroleum fuels it means two things. First, it means an increased level of energy security as a result of increasing domestically sourced diesel, hence limiting the shock felt from petroleum price fluctuations. Secondly, it enables countries to save their hard earned foreign currency to devote to other development priorities that require the outlay of internationally tradable currencies.

6. Sensitivity to inputs and outputs

As illustrated in Table 1, the actual capital cost of production of biodiesel is a relatively small proportion of the total production costs. There are four important areas that ultimately impose a significant bearing on the viability of biodiesel. These include costs of diesel in the domestic market, the price of feedstock, the cost of oil seed crushing and the price obtained for the meal (co-product). The sensitivity analysis below is carried out using 9% discount rate and by varying the value for each sensitivity factor but keeping other costs constant.

The cost of feedstock is the dominant factor in determining final production cost given that it accounts for over 75% of the total cost. For example, at current price of palm seed of $160/t, the total annual operating cost of producing biodiesel in Ghana amounts to about $112.6 million (Table 1). Of this total, the price of oil palm accounts for over 85% of the cost, indicating the significance of feedstock as a decisive factor in determining the viability of biodiesel programmes. In the sensitivity analysis of feedstock costs illustrated in Fig. 4, the break-even cost of jatropha (Tanzania) and castor (Kenya), assuming all other costs remaining constant are shown to be approximately of $240 and $325 per ton, respectively. When the price for feedstock is above this figure, operating losses would result that compromise the cost-effectiveness of biodiesel as an alternative fuel. For biodiesel programmes to create a positive net return, it is therefore imperative to acquire low-priced feedstock, which means identifying ways in which the oil plants that can be grown cheaply and reliably.

Another source of risk involves changes in the retail diesel prices. Uncertainty in the world oil market over the past 5 years has created some alarm about the implications this will have on countries that are strapped for cash. Fig. 5 shows the relationship between the net return (revenue) per litre against a range of diesel prices. The break-even cost of biodiesel from jatropha and palm oil, assuming all other costs remaining constant, follows a similar pattern of about $0.70 and $0.78 per litre, while the minimum selling price of castor-based biodiesel would need to be around $0.93 per litre. When the price of diesel goes above these thresholds, the programmes in the respective countries create positive net returns, but when the price of diesel comes down, it means that the cost effectiveness of the biodiesel programme is in question.

The revenue earned from the crushing and refining process (from vegetable oils to usable energy) makes a crucial contribution to the overall viability and competitiveness of biodiesel programmes. Here, the price obtained for the meal (co-product) is an important cost factor, but is dependent on the market for it locally, which means that the price for the meal is commensurate to the monetary value the end-users attach to it. The sensitivity analysis, presented in Fig. 6 shows that there is a considerable variation in

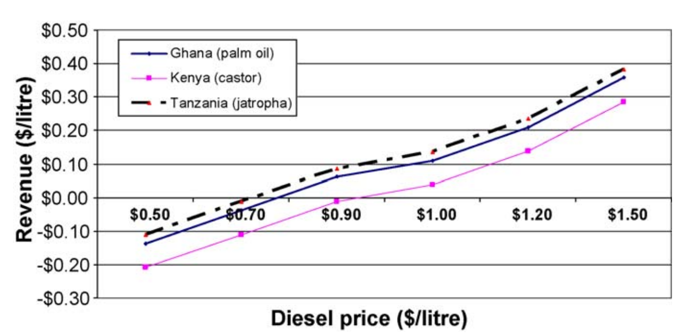

Fig. 5. Diesel price sensitivity at 9% discount rate.

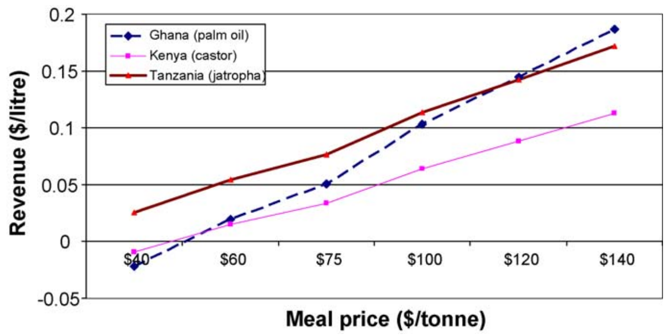

Fig. 6. Meal price sensitivity at 9% discount rate.

revenue as a function of meal price. For the three cases in this paper, every $10 difference in meal price represents on average of about $10 to $20 per 1000 l difference on revenue, hence illustrating that the business case for biodiesel initiatives would need to be incorporate analyses of market for co-product.

Extraction of oil from oil seeds can be carried out by mechanical means or by using a solvent extraction stage into the process. Prior to the removal of the crude oil from the seed by crushing or pressing, there are a number of preparation stages including seed cleaning, removal of seed coat, flaking and heating of the flaked seed. Each of these stages is labour and energy intensive and adds to the operation and maintenance costs in addition to the potentially high-capital outlay for the oil seed crushing equipment. Fig. 7 shows the sensitivity analysis of crushing price per ton of oil seed. A range of crushing price from Canada ($70/t, Government of Alberta), UK ($40/t [12]), India ($30/t [13]) and Brazil ($15/t [14]) are used to illustrate the effect crushing price will have on overall economics of a biodiesel programme.

It is evident that crushing price can play a significant role in determining the viability of biodiesel from different feedstock in a given time and context. One striking feature from Fig. 7 is the relatively steep gradient of the palm oil line, which indicates a diminishing profit margin with rising crushing price compared with castor and jatropha. The main reason for this trend is the lower proportion of 20% oil yield from palm, which is lower than the 30% and 36% oil yield from castor and jatropha, respectively. This also implies that larger proportions of raw material are processed through the crusher plant in the case of palm oil, increasing the running cost of crushing in terms of labour and energy inputs and therefore eating into the profitability of biodiesel from oil palm. For example, a $10 difference in crushing price for the Ghanaian palm oil option represents a $27 difference for every 1000 l of biodiesel produced. This is in stark contrast for the jatropha and castor options which recorded a difference of about $18 and $15 revenue for every 1000 l of biodiesel from jatropha (in Tanzania) and castor (in Kenya), respectively. Of course, the impact that crushing price will have on overall costs needs to be considered in conjunction with other production expenditures for feedstock and other inputs, and income obtained from selling biodiesel and other co-products such as a the meal (cake) and glycerol.

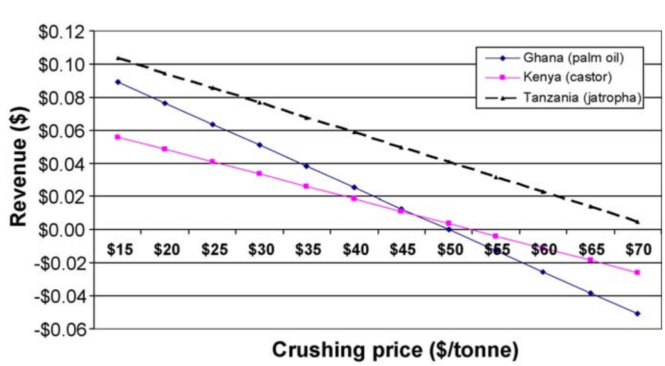

Fig. 7. Crushing price sensitivity at 9% discount rate.

7. Discussion

The observations made so far highlight the range of economic variables associated with the range of biodiesel feedstock in the market. These include yield per hectare, crushing cost and meal price sensitivity. The price of land area placed under cultivation for biodiesel feedstock is also another productivity factor, which is can potentially influence the final price of biodiesel, and therefore the viability of the programme. The price of land in the three countries covered is not incorporated in this paper due to complex land tenure arrangements in all three countries. Future studies would need to take the price of land in the economic calculation of biofuels programmes.

Additionally, there are two other important reasons why the results in this paper need to be handled with some care. First, the calculations carried out do not take into account tax on fuels. The results assume that the governments in the three countries considered in this study would give tax exemptions for domestic sales in order to stimulate the biofuels market and to facilitate return on investment. This is crucial at least in the early phase of biodiesel programmes given its promise of important potential benefits to the national economy. For example, a $0.10 tariff on each litre of biodiesel would place enormous burdens on investors in the biodiesel sector so much that their survival in the fuel market may become difficult without transferring some of the tax burden to the consumer. Such a move would need to ensure that the competitiveness of biodiesel against petroleum diesel is sustained in order for biodiesel to maintain a foothold in the diesel fuel market.

Secondly, the factors of production in Sub-Saharan Africa and elsewhere in the developing world are bound to be different from those in industrialized countries for reasons of differences in technological and managerial capability and labour costs. Much of the production data used in this study is obtained from experiences in Europe and North America due to the lack of empirical experience with respect to biodiesel production in Africa. At present, oil palm and castor are grown at a small scale in parts of Sub-Saharan Africa where productivity per hectare of land area is likely to be lower than used in this study. The feasibility of biodiesel programmes is therefore dependent on the benefit and costs at each stage on the commodity chain, i.e. from feedstock productivity up to the bio-refinery stage. It means yield would need to be improved with improvements in inputs and management for the crops, as well as state-of-the-art technology for pressing oil and larger scale production [15].

Finally, it is important to remember that the principal driver of the discussion to consider biofuels in Africa is energy security. Oil-importing countries would like to reduce their dependency by using substitutes for fossil fuels from indigenous sources, and given land is 'readily available', biofuels represent a logical option towards energy independence. While this may be true up to a point, there is also an argument that the linear extrapolation of diesel demand may mask the shape of real demand, which may have been suppressed by limited supplies and high prices. In other words, market dynamics include other non-linear behaviours such as 'feedbacks' as in the example of increased supply of biodiesel reduces fuel prices. The effect of lower prices reduces the per-kilometre cost of driving,

which may lead to an increase in the total number of kilometres driven. The economic principle that leads to increased levels of consumption as a result of actions that improve technology and reduce consumer costs is widely known as the 'rebound effect'—an extension of the 'law of demand'. While there is a net increase in energy security after the rebound effect occurs as well as increased consumer benefits from increased vehicle travel, the rebound effect can significantly change the nature of the benefits from the original plans. It is therefore important to take into account the degree of the 'rebound' when evaluating a biofuels programme by surveying the level of suppressed demand in the diesel market.

8. Conclusion

Economic activity is something to be welcomed in Sub-Saharan Africa where this has been elusive over the past 40 years. However, the increased transport activity associated to economic activity comes at a price. Since 2004, world fuel prices have been rising, reaching US$70 in late 2006 (and exceeding the $130 mark in 2008), which is placing considerable pressure on the economies of oil-importing African countries in particular, and threatening the modest progress made over the past few years. In search of alternatives, a number of countries have started to look closely at biofuels as one route towards withstanding the pressure from a volatile oil market and creating a more secure supply base that can be accessed domestically.

This paper carried out an economic assessment palm oil in Ghana, jatropha in Tanzania and castor oil in Kenya as the feedstock for producing biodiesel. The economic analysis used production and input data from other studies, mainly in North America and Europe, and therefore provides an indicative price range for biodiesel production cost and revenue. For more robust results, data from the actual plantations and processing plants would need to be gathered and analyzed. In the absence of such data, this paper relied on best available data in the public domain. The economic analysis (levelized cost) of production and revenue at three different discount rates (5%, 9% and 12%) were carried out. The results of potential revenue per litre show that palm oil performed slightly better than jatropha, with castor trailing far behind. The reason for this is that the yield per hectare for palm is significantly higher than the other two. Another reason is also the meal (by-product) for palm oil after crushing is considerable, and can be used as animal feed as well as fertilizer, whereas for jatropha and castor, the meal can only be used for fertilizer. The sensitivity analysis showed that meal price and feedstock price are two of the most important determinants of overall production cost and revenue. Still, the performance for jatropha is interesting, especially since the plant is known to be sufficiently resilient to grow under a range of climatic and soil conditions.

The decision to embark on a biofuels programme is not only contingent on economic concerns alone but also there are a number of broader issues such as to land use, potential conflict with food production, deforestation and effect on water table that need to be taken into consideration. These will be discussed in a follow-up analysis.

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